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Technical Note N-662

UNDERWATER MOORING SYSTEM

BY

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7 April 1965

U.S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

INTRODUCTION

In 1960, at the request of the U. S. Navy Underwater Sound Laboratory, New London, Connecticut, this Laboratory (NCEL) initiated development of a container for a Master Repeater Unit (MRU). The general purpose of this task was to develop equipment and techniques for protecting an instrumented package moored below the ocean's surface in depths as great as 15,000 feet.

In order to positively establish the life expectancy of the equipment, it was necessary to conduct numerous tests in the actual sea water environment. The life test of a special polyethylene coated mooring cable is the subject of this report.

BACKGROUND

It was essential to limit the size and weight of the mooring system. The corrosive environment of the sea is particularly destructive for unprotected steel elements such as individual wire filaments of cables. Therefore, if the more conventional techniques were to be utilized, the size and weight of the mooring cable would, of necessity, be large. In turn, the buoyant container necessary to support this weight would also be large, a condition which was completely unacceptable in this situation.

The alternative to the above approach is to rely upon some of the newer plastic filaments in lieu of steel. Some of these have been proven durable in the corrosive sea. Some, in fact, are themselves buoyant in sea water and thereby do not add to the size requirement of the buoyant chamber. Some are attacked by marine life. Some are elastic and thereby would be difficult, if not impractical, to use in a situation requiring closely controlled limits. Most are bulky in relation to strength to size ratios. This sets limits on the method and equipment used in planting the mooring systems.

The approach selected by the Laboratory was to find a high-strength, small-diameter steel cable, adequately protected against marine life and corrosion. The cable selected and one of the methods devised to test it is described in the following paragraphs.

wires. The container, a 32-foot-long, 20-inch-diameter cylinder of 3/8-inch wall steel pipe with welded-in-place bottom and a flanged top had a removable cover plate. It was outfitted with a radio signal transmitter (Figures 7, 8) powered by 48 dry cell, 1-1/2-volt batteries wired in series (Figures 9, 10, 11). The radio was designed to be activated by reduced hydrostatic pressure on a pressure switch in the event the cylinder rose to the surface. A whip antenna (Figure 12) of stainless steel was mounted on the outside of the container lid. The container assembly had a net positive buoyancy of 700 pounds.

A slipring assembly (Figures 2, 4) was attached to the bottom end of the container and a swivel was attached to its lower end. A 600-foot length of Wickwire was made fast to the slipring and a 400-foot length of the Vitro test cable, with end socket connections potted as indicated by Figure 13, was attached to the swivel. The method of potting the cable into these sockets ensured that the test cable would part, under strain, before the cable would pull free of the socket (Figure 14). The other end of the 400-foot test cable was attached to a 1500-pound concrete clump similar to that shown in Figure 15. A second swivel was also attached to a second pad eye on the concrete clump and 600-feet of common quality 1/2-inch steel cable was attached to this swivel.

The 600-foot cable was then used to lower the 1500-pound clump to the sea floor. First, however, the 19-inch buoy was passed to an assist boat. The container was placed in the water, at which time the transmitter antenna was installed (Figure 12). The assist boat then towed the buoy and container away from the YFU the length of the 400-foot Vitro test cable. The assist boat kept tension on the test cable (Figure 16) to prevent it from being twisted and entangled about the 1/2-inch clump-lowering cable. During this operation, the Wickwire attached to the slip-ring below the container was also payed out. When the 1500-pound clump was on the bottom, the end of the 1/2-inch lowering cable which remained on deck was made fast to a second clump (2264 pounds). A 400-foot length of Wickwire was attached to this clump to serve as a lowering line.

As the second clump was lowered away, the YFU stern anchor line was taken in. The lowering line was stopped off near its end and a swivel attached. A second slipring assembly was attached to this swivel. The free end of the 600-foot Wickwire attached to the first slipring was connected to this second slipring. A 42-inch-diameter metal spherical, closed-cell foaming-plastic filled buoy was then attached to the slipring assembly. Two 100-foot lengths of 1/2-inch cable were attached to the 42-inch buoy, one to the upper and the other to the lower pad eye. The cable attached to the lower pad eye was used to lower the clump. With the second clump on the bottom, a 54-inch metal spherical buoy (Figure 17) was attached to the lowering cable for use as a marker buoy. The second 1/2-inch, 100-foot cable was also attached to this marker buoy at its top pad eye. This procedure was designed to ensure that the 54-inch marker buoy would not

become separated from the test assembly; however, after 25 days, this marker buoy was found adrift. The drifting components are indicated by an encircling dashed line on Figure 2. Upon examination after retrieval, the cable appeared to have broken under tension rather than through chaffing. The rest of the test assembly was found to be intact.

PURPOSE OF COMPONENTS

The reason for the arrangement of the assembly was as follows:

The dummy container was to provide simulated effects of the 700-pounds positive buoyancy of an actual MRU container on the Vitro test cable. The stabilizing arm on the container was to minimize the tendency of the container to rotate in the water. This effect was aided by the strain due to the 19-inch buoy.

The 19-inch buoy was to simulate the proposed MRU surface element and its added effect on the test cable due to drag and surface motion.

The upper 600-foot Wickwire cross-member was to restrain the container in the event that the test wire was parted. In such event, the container would rise to the surface as in Figure 12. The batteries were loaded into the bottom of the container, by use of the rack shown in Figure 11, to keep the center of gravity low so that the container would float with the long axis vertical. If the container surfaced, the pressure switch would activate the transmitter, which would transmit a signal to NCEL where it would be picked up on a recording receiver. NCEL personnel would then arrange retrieval. The lower 600-foot-length of 1/2-inch cable was to be used in retrieving the assembly if the test cable did not part during the test period.

The sliprings were to allow the upright portions of the assembly to be rotated about by currents without tangling the upright and cross-member cables. The swivels were to prevent twisting or unlaying of cables causing tangling during installation.

The lower 42-inch spherical buoy (plastic-filled) was to support the retrieval system in case the surface 54-inch marker buoy should become separated. In the event both surface marker buoys were lost, the upper 600-foot Wickwire cross-member would serve as a snag for dragging operations.

TEST PROGRESS

On 14 August 1961, divers from NCEL followed the line from the 19-inch spherical surface buoy down to check the container. They found it

to be in order and their depth gages indicated that the top of the container was down 90 feet. A new 19-inch buoy with identification data was attached to the assembly, replacing the original buoy. On 1 September 1961, a separate marker buoy (275-gallon barrel buoy, Figures 18, 19), (Figure 1, Marker Buoy #1) was installed 1/4 mile shoreward and in line with the installation and the pier. Its purpose was to facilitate locating the installation in the event the original marker buoys were lost.

During October 1961, the small 19-inch marker buoy was reported missing and the assembly was located by dragging. A 19-inch spherical buoy was attached to the 600-foot cross-member wire by a length of Wickwire. This buoy attachment was free to slide along the cross-member.

On 26 January 1962, it was noted that the large (Figure 1, Buoy #1) marker buoy (275-gallon barrel) was low in the water, possibly due to an accumulation of sea growth. This buoy was replaced by an identical buoy. It was also decided to remove the small 19-inch buoy to alleviate danger of its fouling the mooring system. First, however, this buoy was used to determine a location for a second separate 275-gallon barrel marker buoy (Figure 1, Buoy #2). This was done by picking up the small buoy and moving to seaward as far as possible without unduly straining the test assembly. The new #2 marker buoy was then lowered into place in line with the pier and the #1 barrel buoy. This would give an indication of where to search in future attempts to locate the assembly.

On 31 October 1962, the shoreward (#1) marker buoy was found adrift, trailing its cable. The cable apparently kept the buoy from drifting any great distance. Attempts to locate the container assembly after this proved fruitless. The Wickwire cross-member either failed on contact, or had previously failed, possibly due to corrosion. Effort to snag the bottom cable was frustrated, apparently by shifting of sands. Two 150-pound steel anchors were towed behind the YFU in this attempt. It was calculated that the anchors were dragging bottom, with less than 200 feet of line out, where the water depth should have been 500 feet or more. The remaining barrel buoy was retrieved and the search discontinued.

On 13 December 1962, a final effort was made to locate the container by dragging. Buoys were placed in approximately the location of the original separate marker buoys, as determined by navigation fixes, and the area between was thoroughly dragged without success. Buoys were retrieved and no further effort was made to locate the assembly.

On 20 September 1964, a private yacht out of Channel Islands Harbor, Ventura County, California, reported an attempt to salvage a strange buoy in a location two miles southwest of the pier at Point Mugu. Upon consultation with the captain of this craft, it was determined that the test container had surfaced. Immediate search failed to relocate the container. On 23 September 1964, the Retrieving Boat, WTB 12, of the Surface Craft

Division, Naval Air Station, Point Mugu, salvaged the container from a position four miles southwest of the harbor entrance of Port Hueneme, California, and delivered it to NCEL personnel.

FINDINGS

With Relation to the Test Assembly

Figure 20 shows the container as it arrived dockside. This photograph shows the extent of sea animal growth accumulated during the period of submergence. This growth (Figure 21) included:

1. Jingle Shells (up to 4-inches in diameter)

   Anomia

2. Serpulid tube worms (large and small)

3. Sea-anemones (some up to 5-inches in diameter at the base)

   Metridium

4. Bryozoa (erect and encrusting form)

   Tricellaris occidentalis

   Phidolopora pacifica

   Zoobotryton pellucidum

   Membranipora membranacea

   Eurystomelia bilabiata

5. Sponge (up to 3-inches in height)

   Rhabdodermella nuttingi

6. Chitons

7. Hydroids

8. Barnacle (up to 2-inches in diameter at base)

   Balanus tintinnabulum

9. Clams

10. Brittle stars (various species)

11. Mussels

    Mytilus californianus

12. Scallops (some up to 5-inches in diameter)

13. Ascidians

14. Sea worms

    Polychaetes

15. Algae

16. Nudibranchs

17. Other small marine fouling organisms such as crust and protozoans.

NOTE: *Anomia* was the predominant marine animal found a to the surface of the container. Its shell had most of the surface.

When several large barnacles attached to the prc coating over the container were pried loose, a s section of the protective coating was removed wi revealing the excellent condition of the protect (Figure 22).

Figures 22 through 33 indicate the condition of the contain various contents and attachments. In general, the container was lent condition. The paint coating had served as an excellent pr Where the coating had been abraded, Figures 23 & 24, some rust p occurred. The antenna had corroded off. The vent hole for the switch, to activate the transmitter, was packed solid with sea g Galvanized shackles and swivel (Figures 25 & 26) showed very lit of submergence except for minor crevice corrosion where they wer tact. Not all of the zinc coating had been removed from these p Vitro test cable (Figure 26) appeared to have parted due to stra sibly as it was finally weakened by corrosion. The unprotected parts of the slipring assembly (Figures 27 & 28) showed remarkab of preservation. Beneath a coating of sediment and marine life black sulfurous slime. The metal showed no pitting. Inside, th showed (Figure 29) only the minor rusting that could be attribut tive moisture impounded at the time of container closure. The t (Figure 30) was operable and the dry cell batteries (Figure 31)

their full charge. A machined surface (Figure 32) on the inside of the lid and matching area on the container flange was still bright. The "O" ring seal, to all appearances, (Figure 32) was as good as new and the steel bolts securing the lid to the container were still usable. The aluminum stem used to insert and retrieve the battery package was not corroded (Figure 33).

The Wickwire apparently was the first corrosion casualty. Only hair-like remains of individual wire filaments protruded from the socket connection.

When a small male plug located in the lid was removed, prior to removing the lid, air was drawn into the container. This might be attributed to a difference in temperature at the time of closing and opening.

With Relation to the Test Cable Compared to Other Cables in the Assembly

The Wickwire (3/16-inch, 3 x 19 Seale construction, preformed, right-regular lay, improved plow steel, galvanized, lubricated) presumably was corroded beyond serviceability on or before attempt at location on 31 October 1962. This indicates a service life of less than 15½ months.

The two 1/2-inch cables (common quality) used in attaching the 54-inch surface marker buoy parted due to unknown causes within 25 days. Since the strength of either of these was much greater than the strength of the Wickwire, it must be presumed that they were chaffed or corroded in spite of the appearance of the severed ends (Figures 34, 35, and 36).

The 3/4-inch cable used to moor the first 275-gallon barrel buoy was parted due to unknown causes after a period of 14 months. Most likely, this was due to corrosion and wear caused by surface motion.

The surfacing of the MRU container on or about 20 September 1964 indicates the service life of the test cable to be approximately 38 months under the test conditions.

CONCLUSIONS

Steel cable of minimum size and strength, but adequately protected, has a longer service life in a highly corrosive environment than a much larger and stronger but unprotected cable.

When encasing a steel cable, a polyethylene sheath serves as an effective barrier to sea water.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of Mr. J. S. Muraoka, Biologist of NCEL, in the identification of the sea life found on the container.

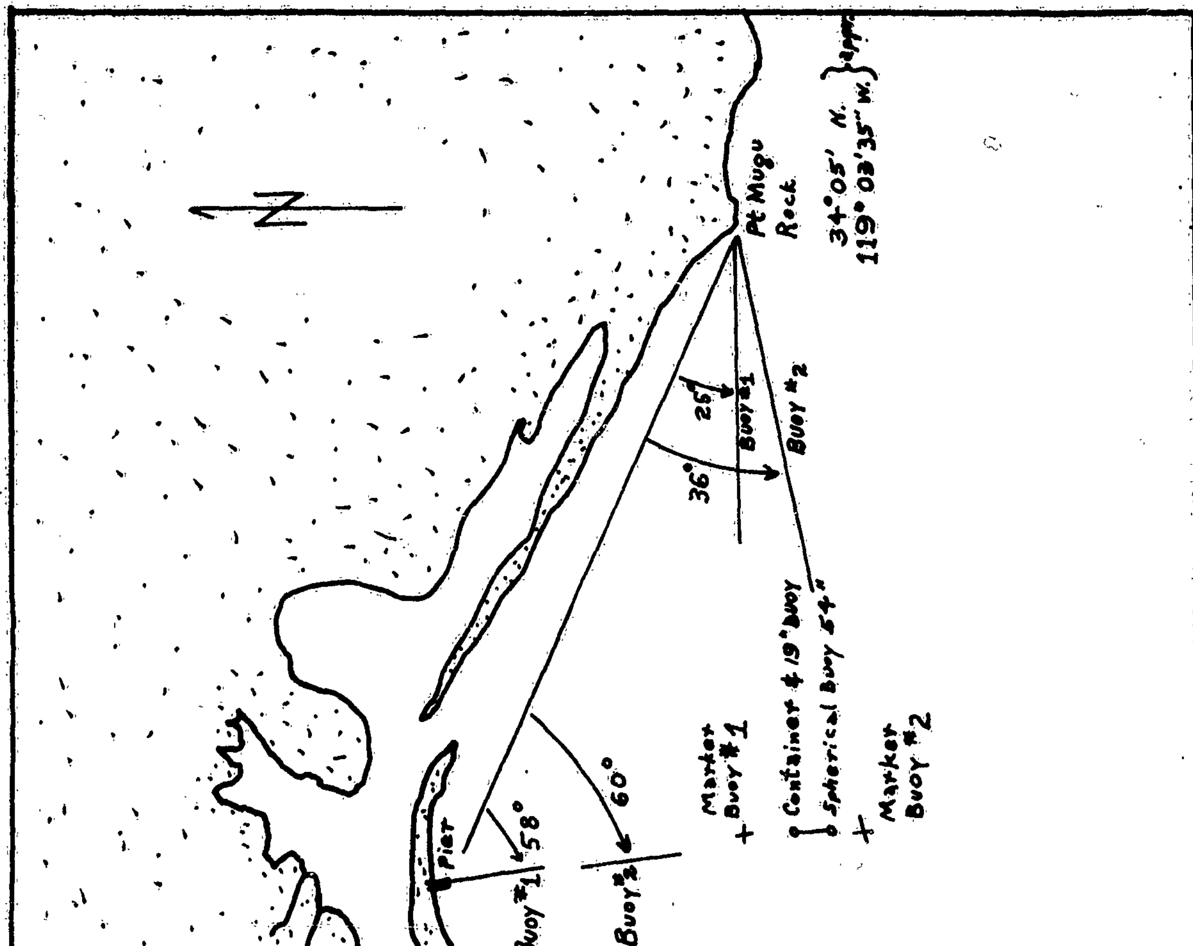

Figure 1. Sketch of test site.

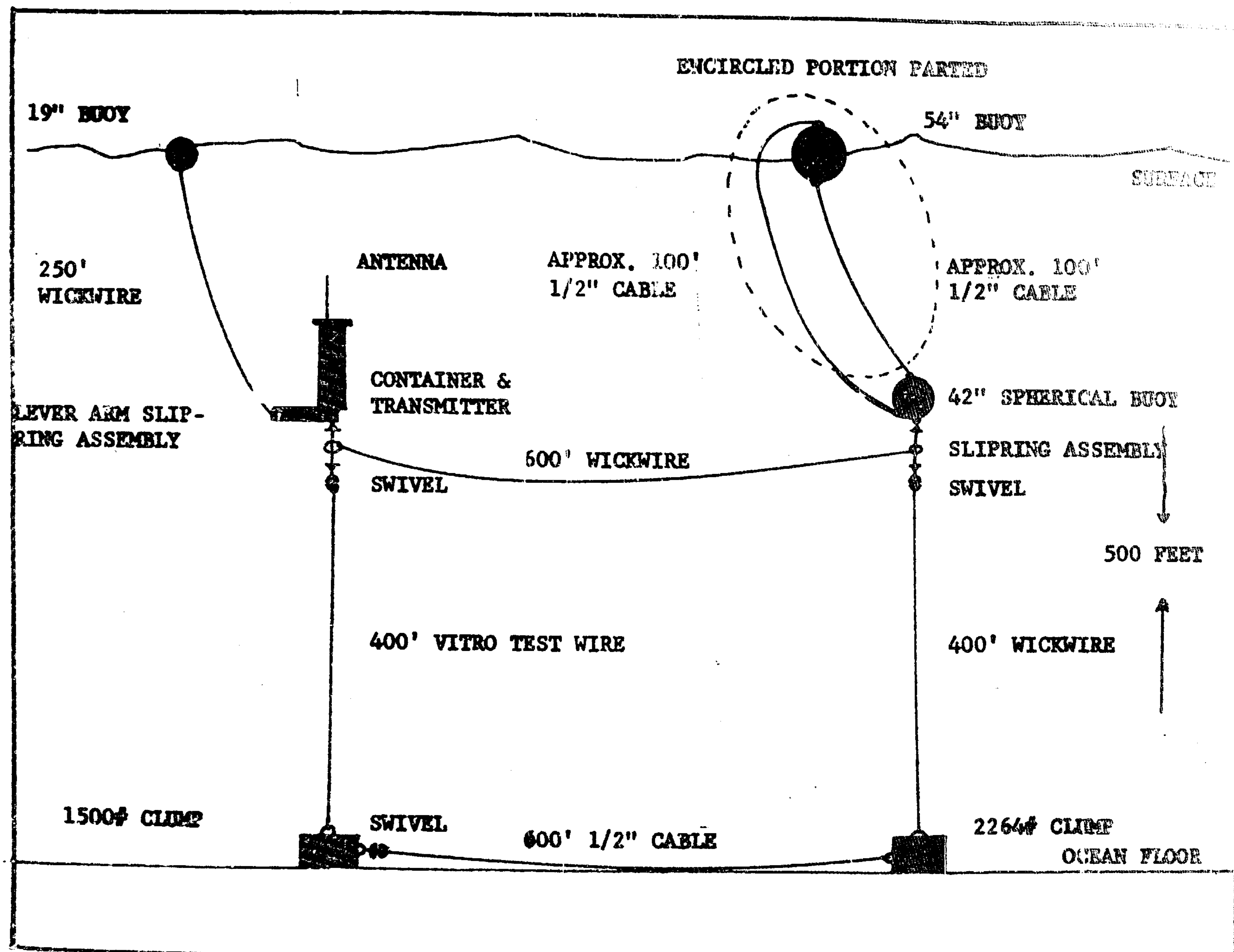

Figure 2. Assembly for Vitro wire test.

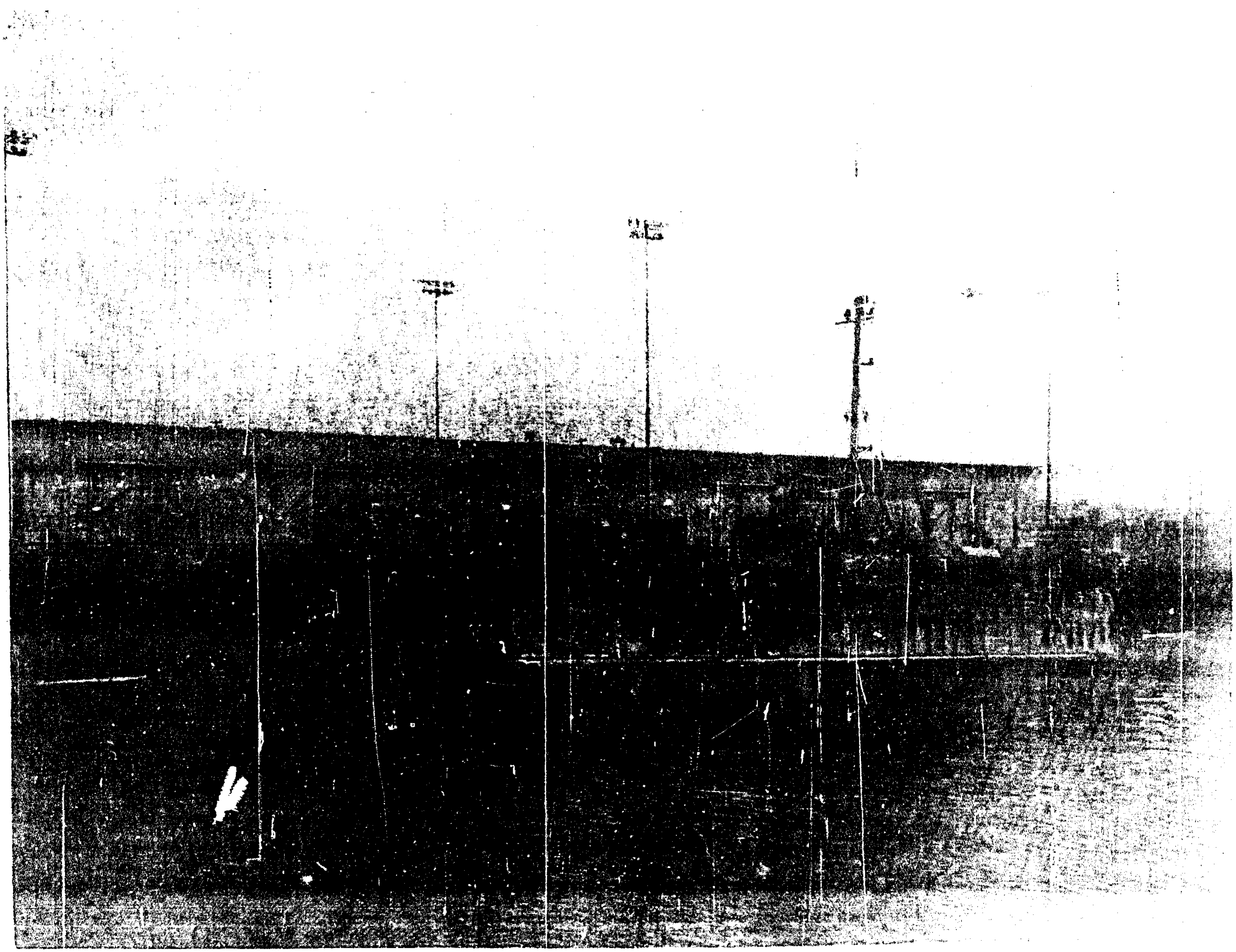

Figure 3. YFU prior to modification and addition of crane.

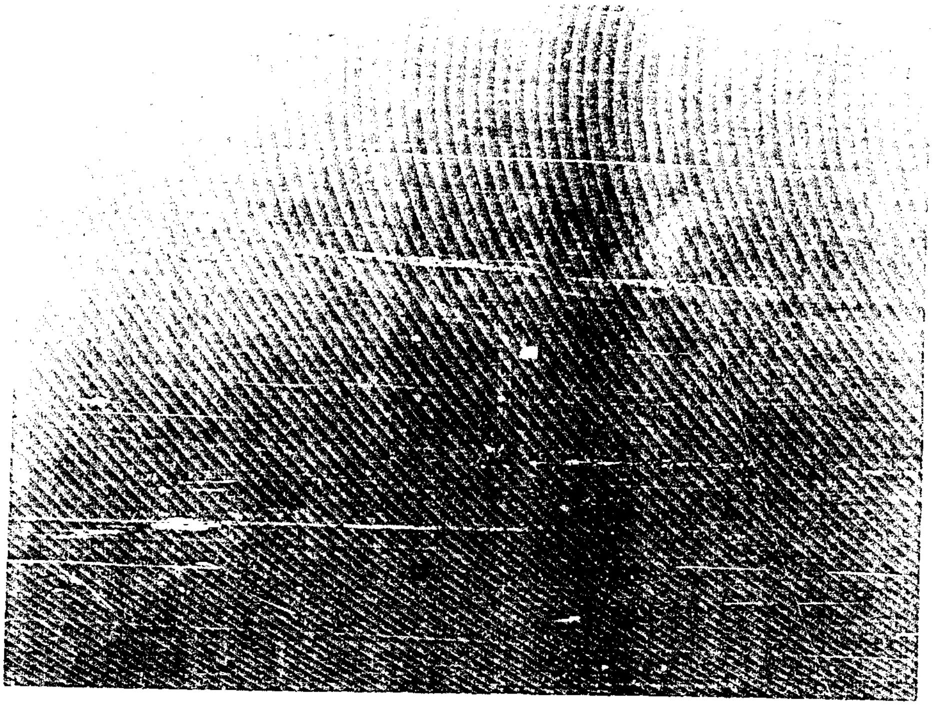

Figure 6. Test container with stabilizing arm.

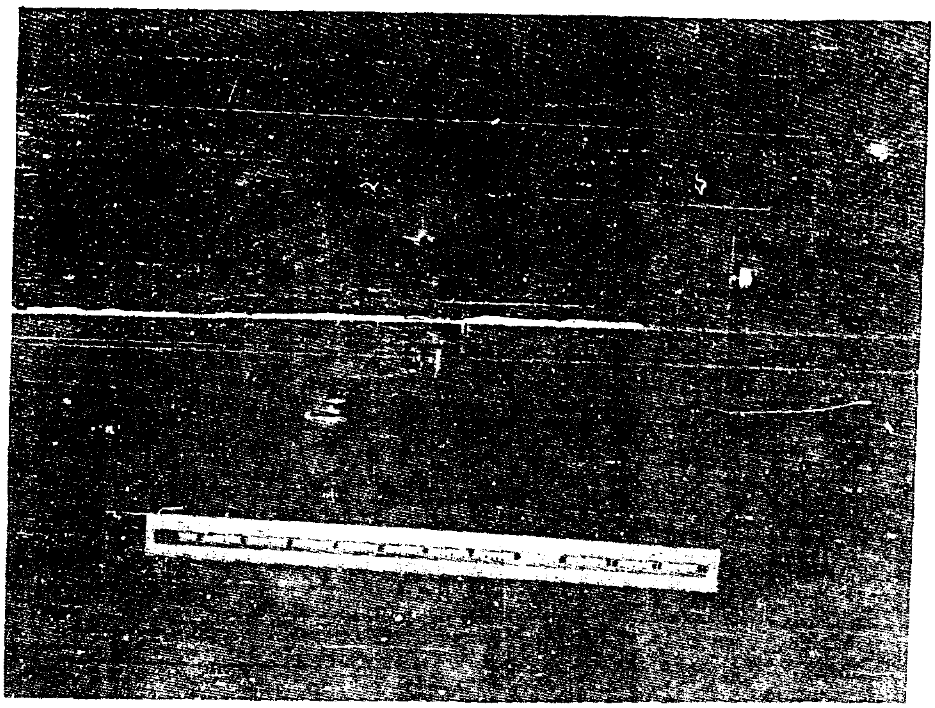

Figure 7. Signal transmitter for test container.

Figure 8. Transmitter and antenna mount installed.

Figure 9. Dry cell batteries installed in battery cage.

Figure 10. Batteries prepared for installation.

Figure 11. Battery cage and installation stem.

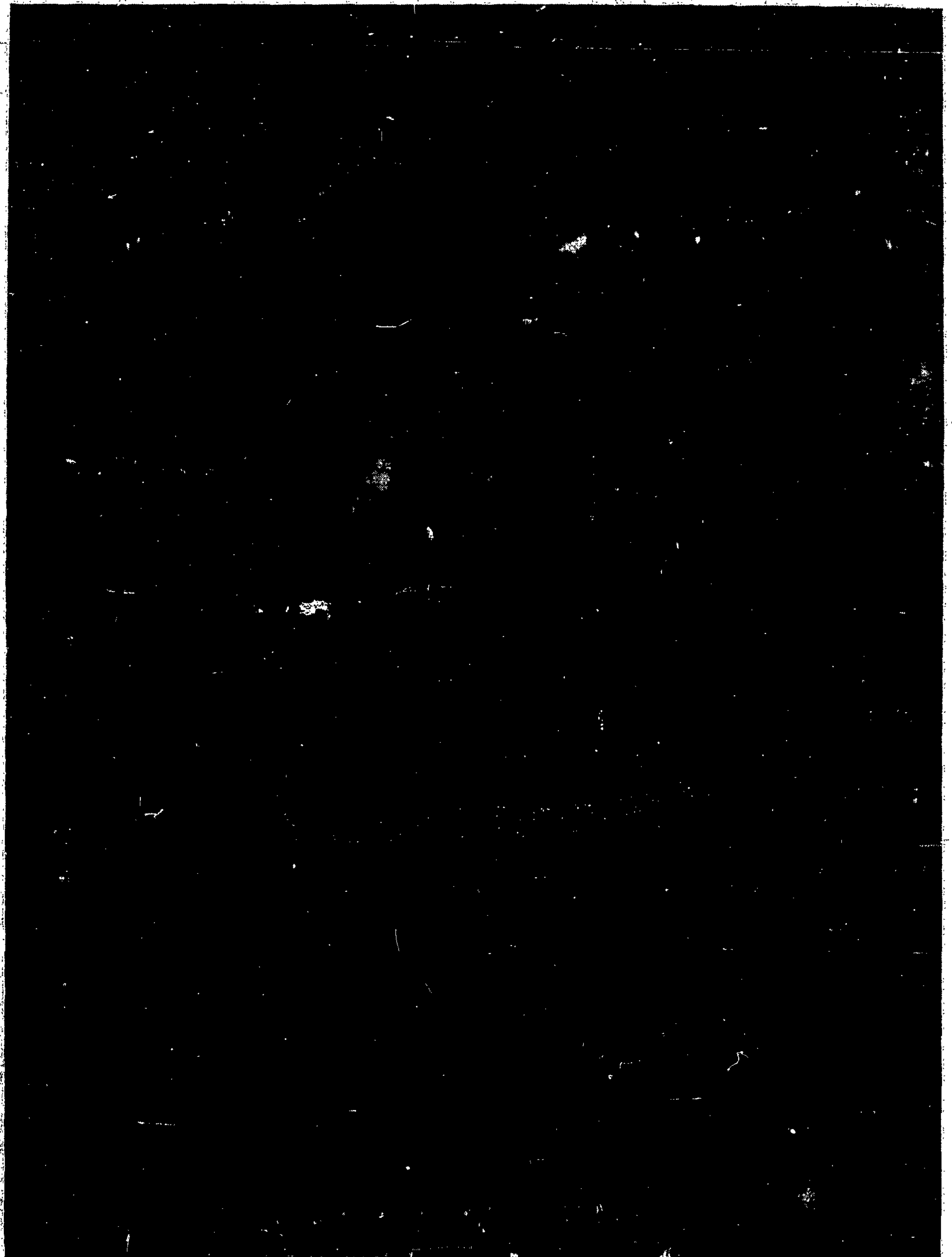

Figure 12. Installing antenna on test container prior to submerging.

Figure 13. Method of securing test cable ends in socket connections with epoxy resin.

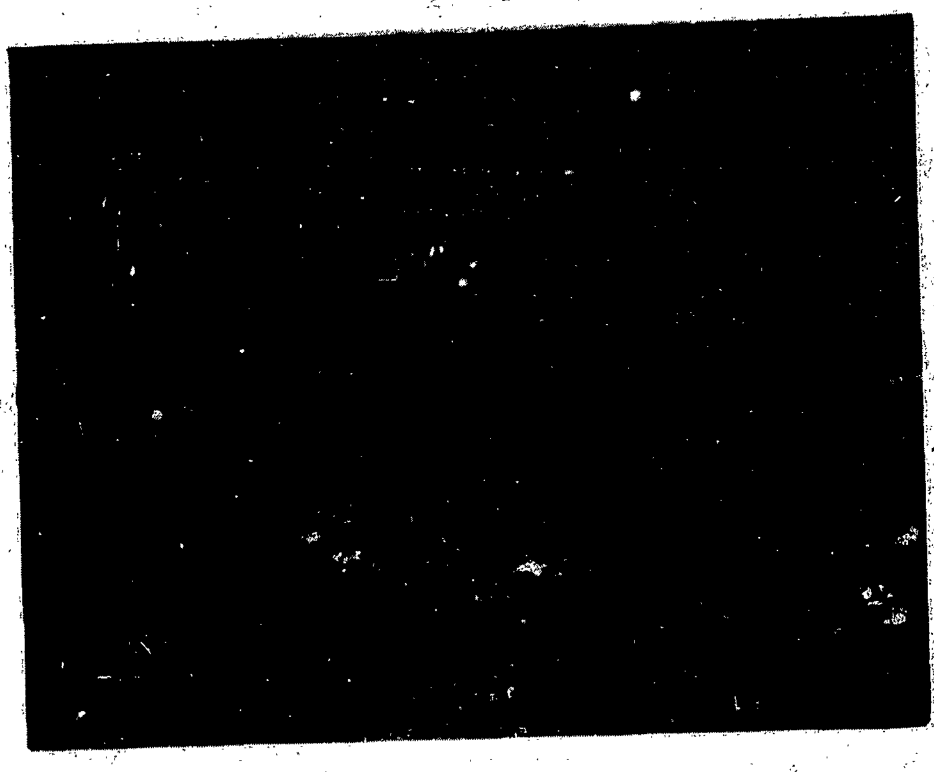

Figure 14. Example of test cable break without disturbing potting in fabricated socket fitting.

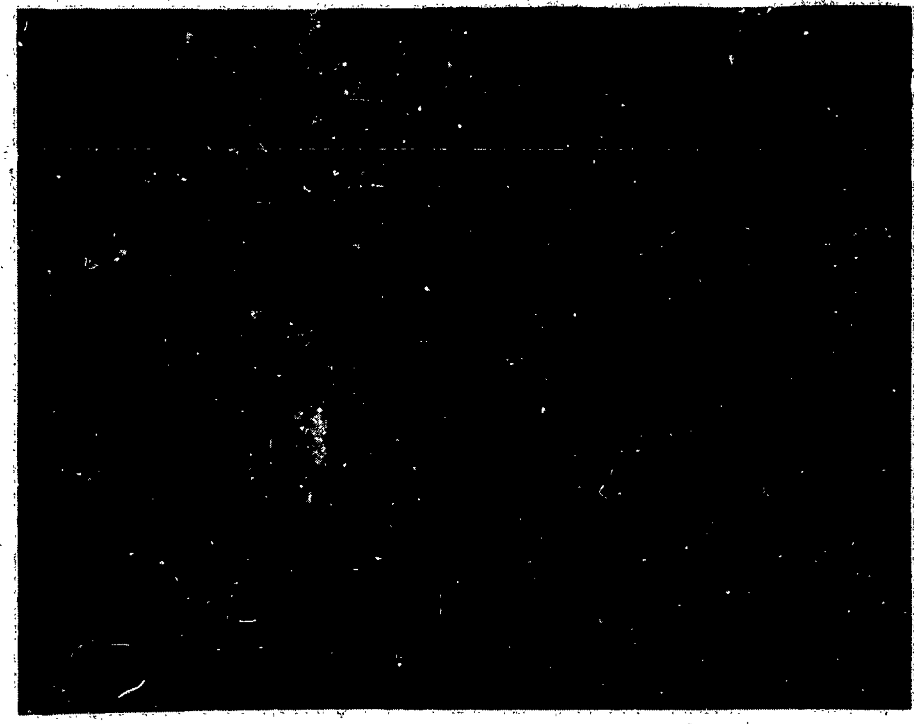

Figure 15. Concrete clump anchor.

Figure 16. Assist boat keeping strain on surface buoy and container during installation.

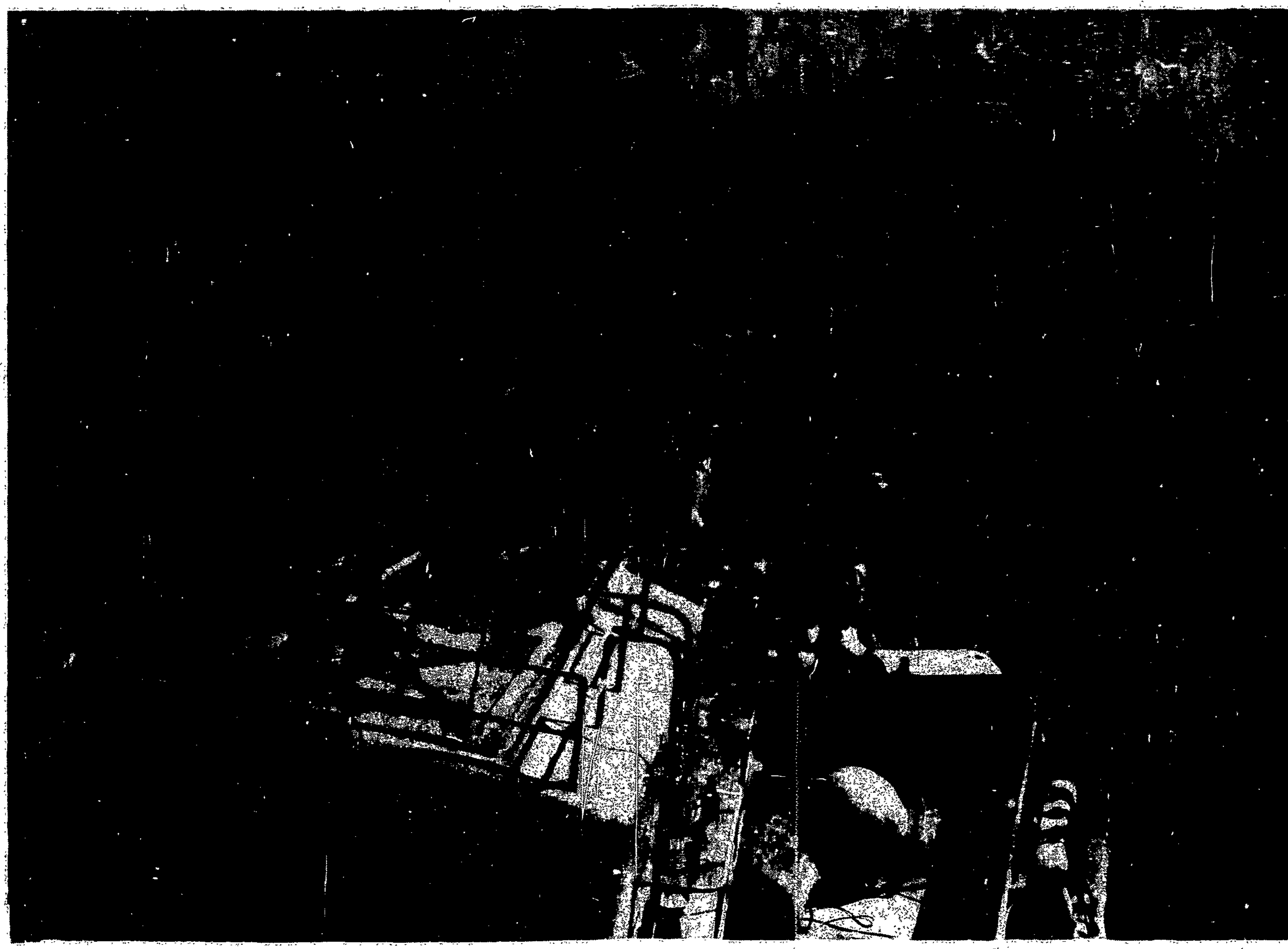

Figure 17. 54-Inch spherical marker buoy.

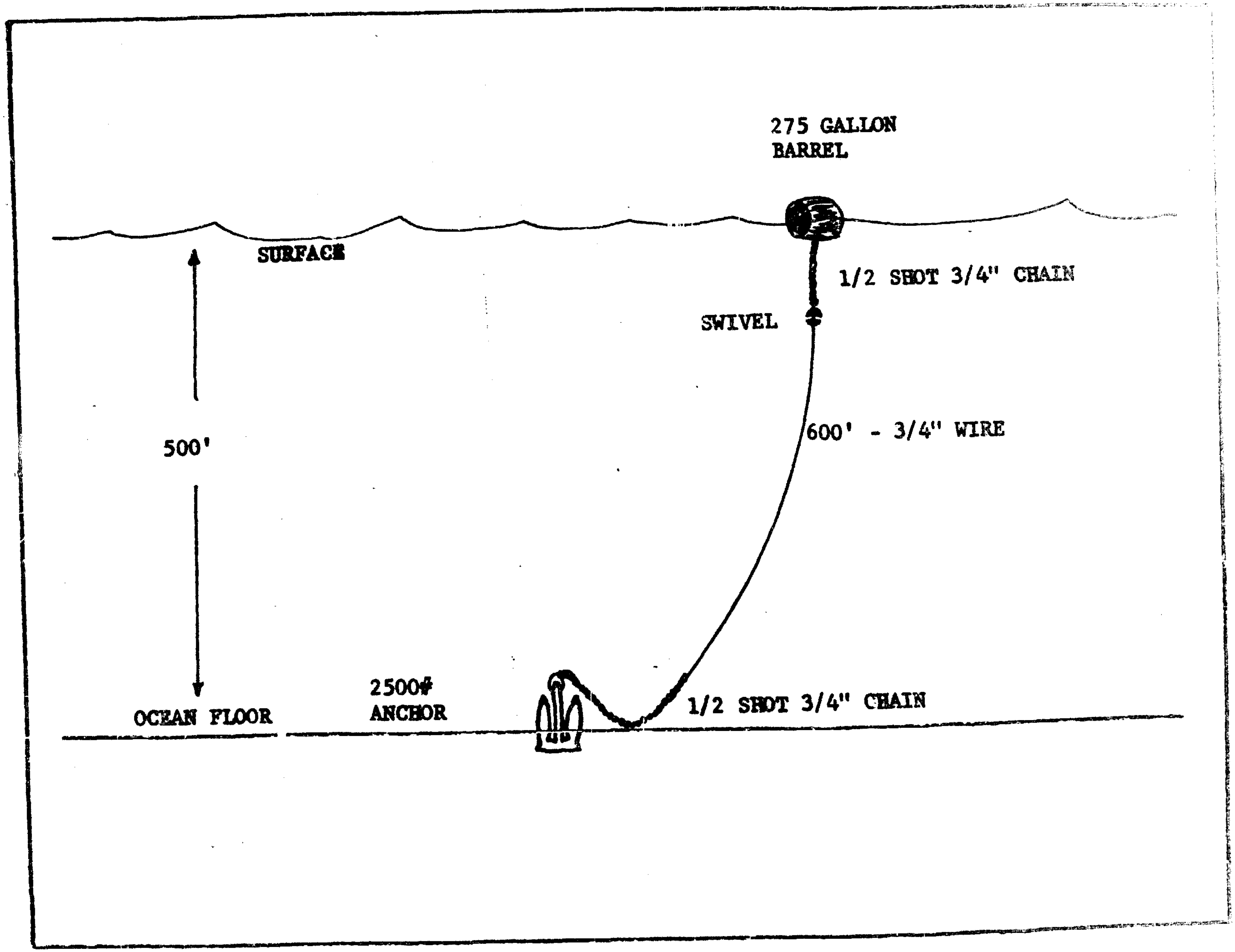

Figure 1B. Marker buoy for 500 foot depth.

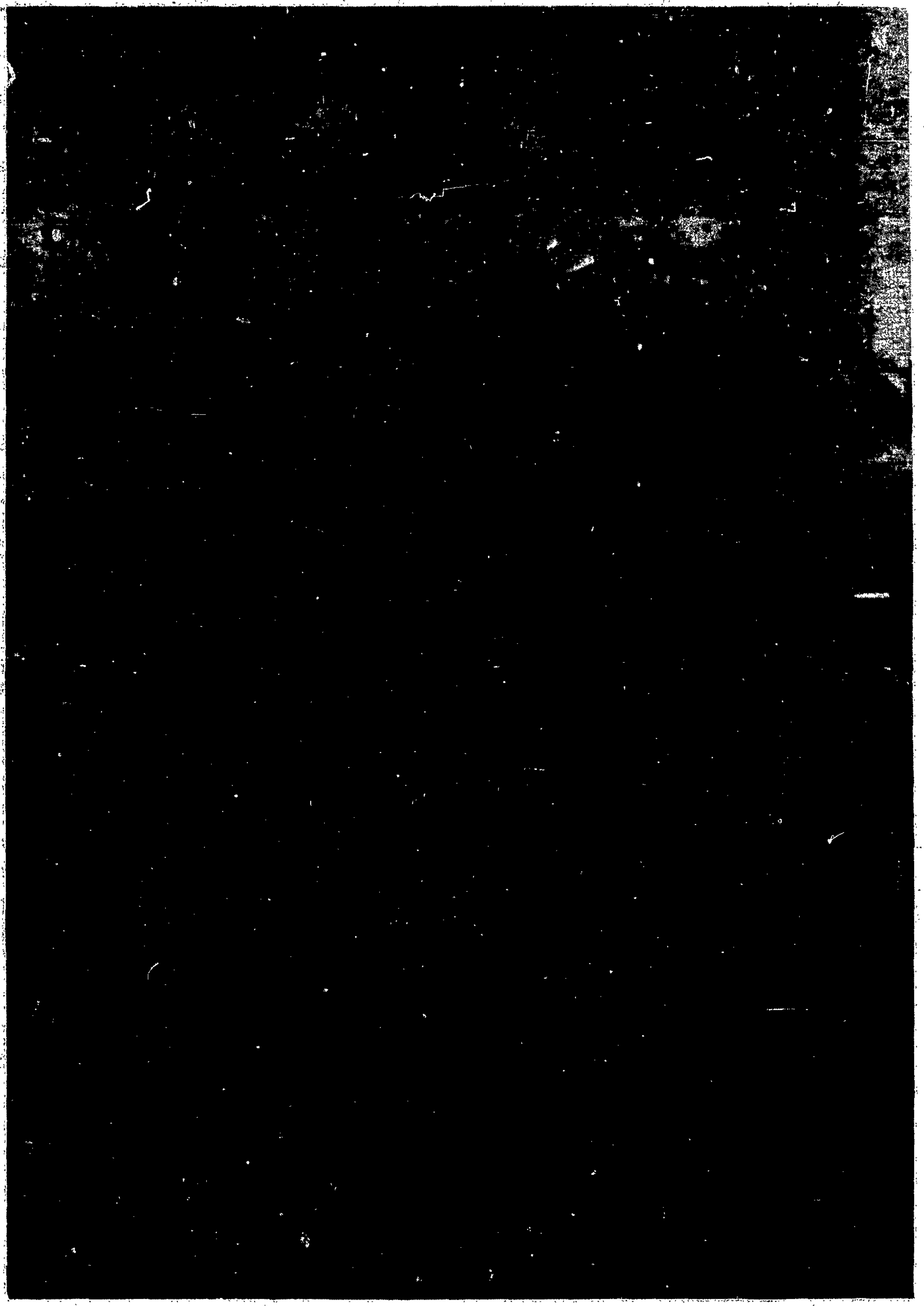

Figure 19. 275-Gallon barrel buoys.

Figure 20. Test container arriving dockside upon delivery by Retrieving Boat, WTB 12.

Figure 21. View of accumulation of marine growth.

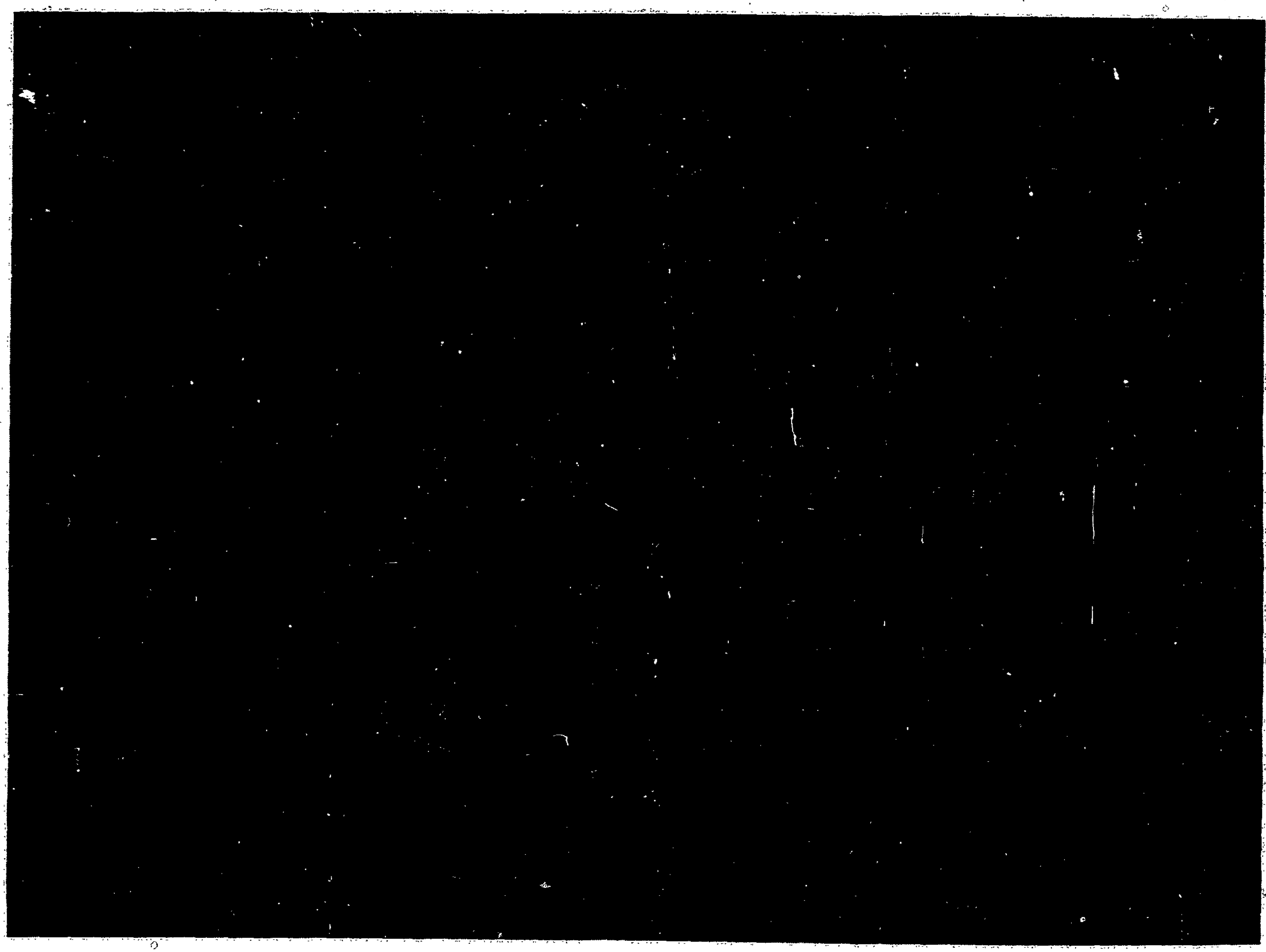

Figure 22. Small section of protective coating removed revealing excellent condition of protected metal.

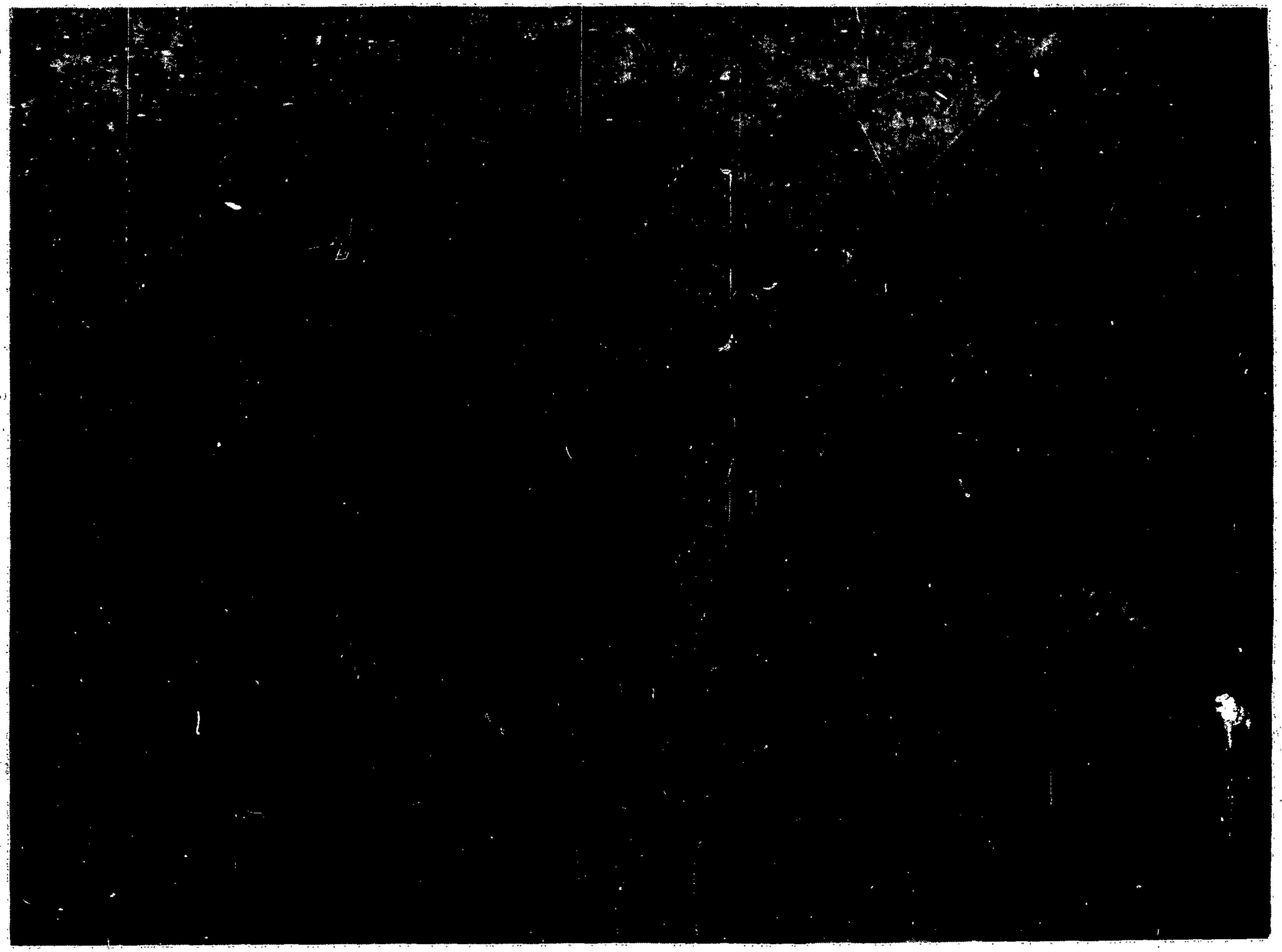

Figure 23. Extent of corrosion where protective coating was abraded.

Figure 24. Pitting due to errosive environment during test and rusting during exposure to atmosphere following retrieval. Note comparison with surface exposed by peeling back coating for photo.

Figure 25. Galvanized shackles following test. Minor crevice corrosion evident.

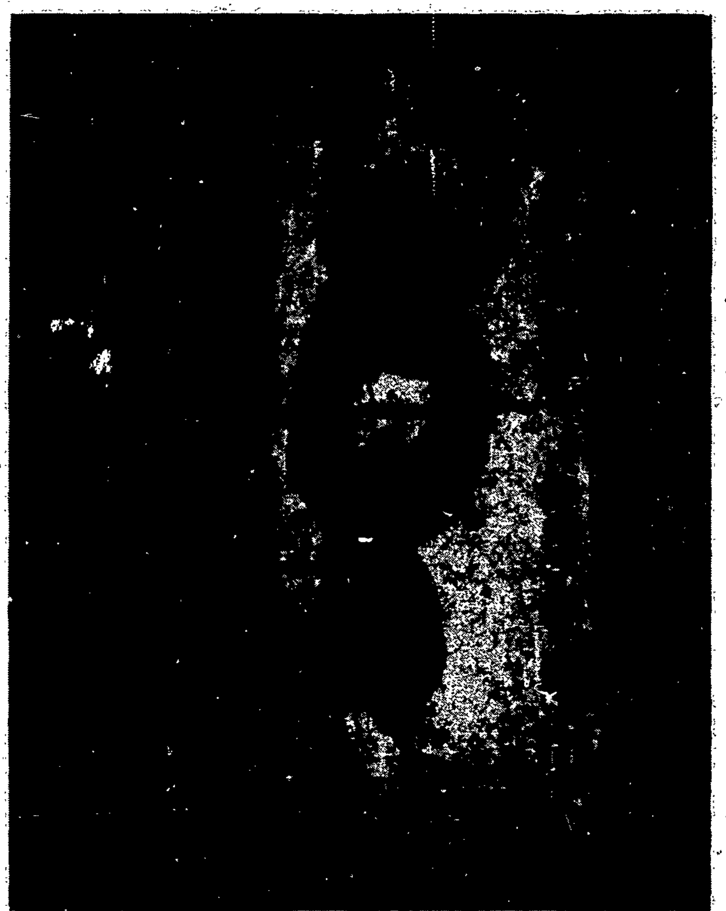

Figure 26. Swivel following test. Note strain type break of Vitro test cable.

Figure 27. Slipring assembly following test. See Figure 28 for close-up of section indicated.

Figure 28. Close-up of the condition of unprotected mild steel shaft of slipring.

Figure 29. View inside container as lid was removed.

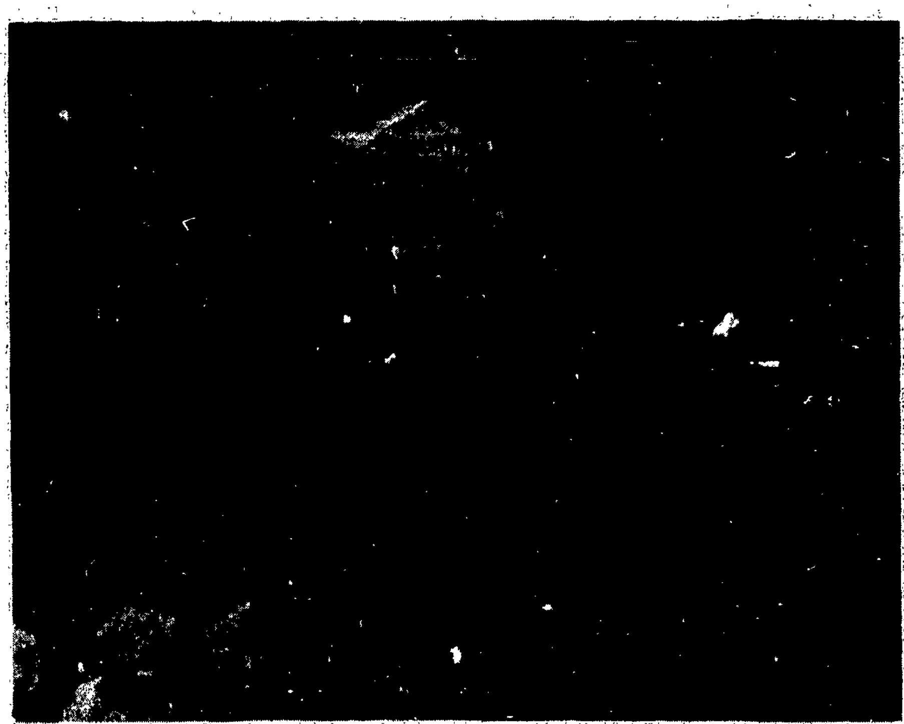

Figure 30. Transmitter as lid was removed.

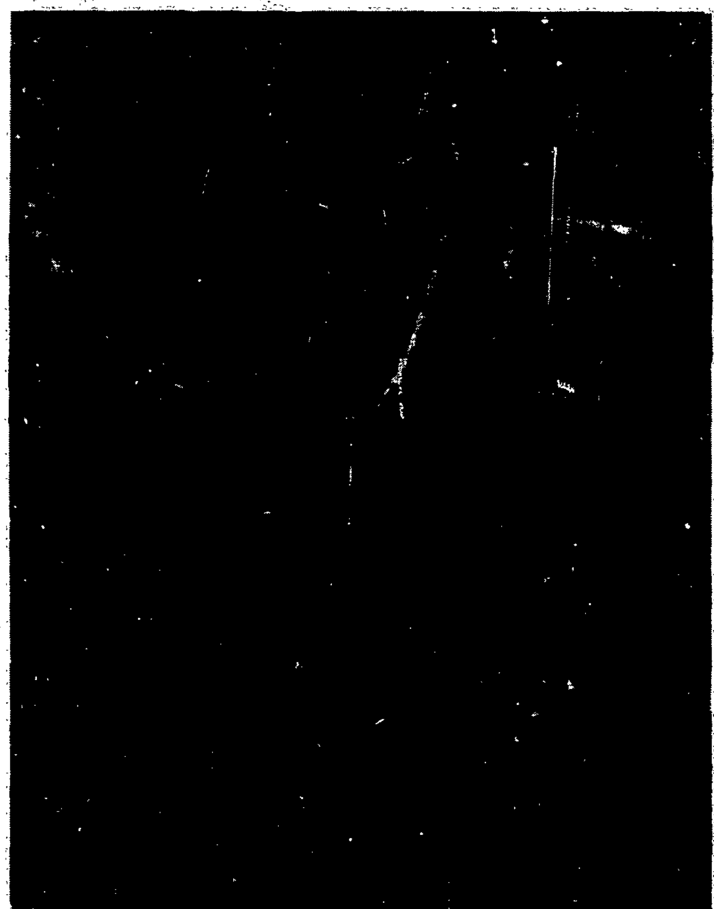

Figure 31. Batteries when removed from container.

Figure 32. View of machined surface inside lid and of "O" ring after test period.

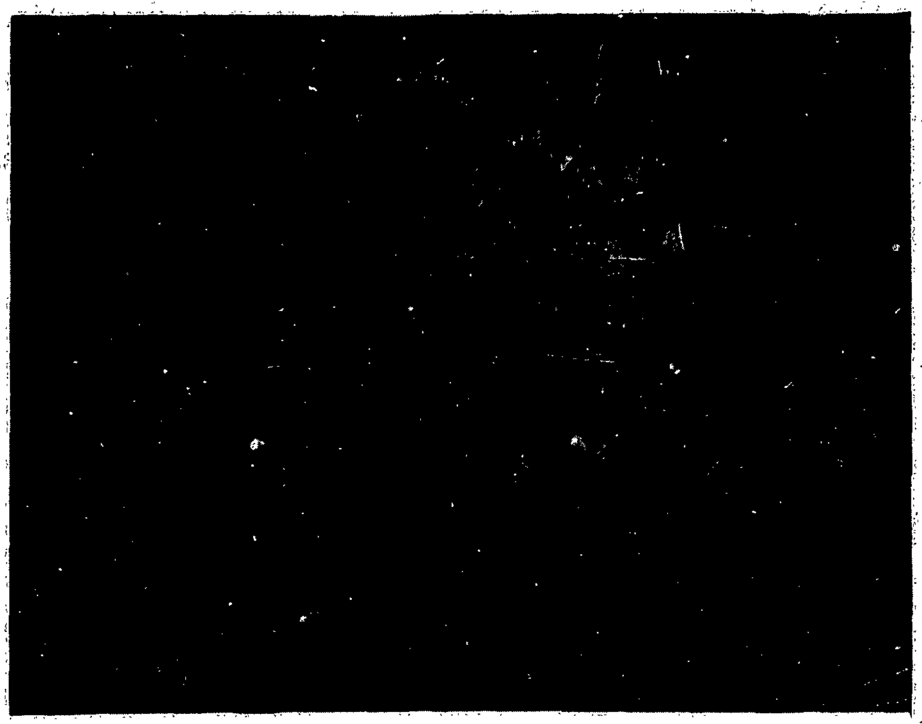

Figure 33. Battery cage installation stem upon removal. No corrosion evident.

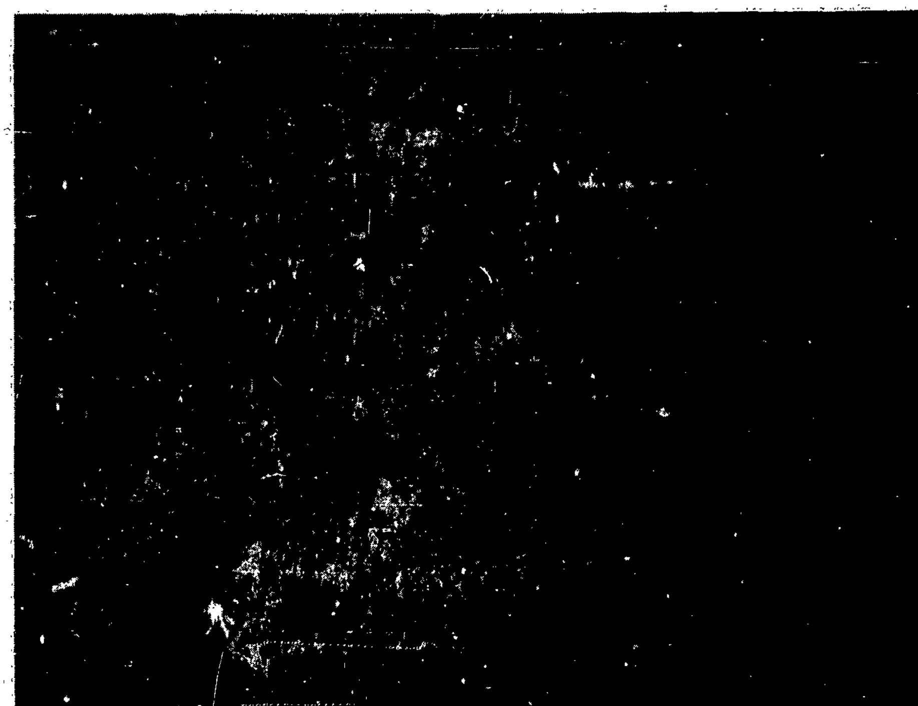

Figure 34. View of damage to ½-inch cable used in mooring 54-inch surface buoy.

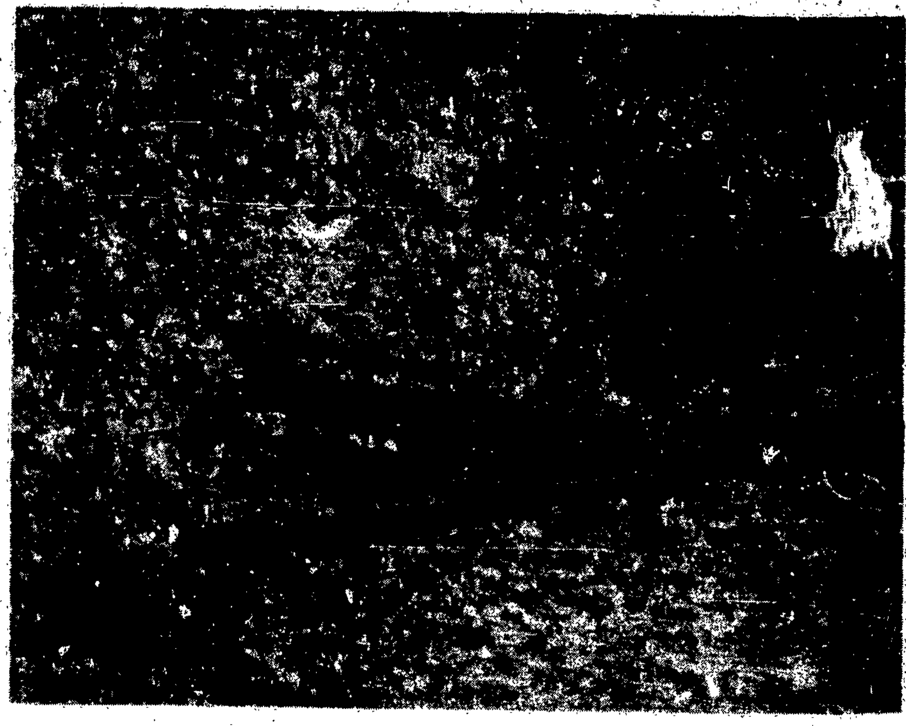

Figure 35. Close-up of damage to 1/2-inch cable end shown in Figure 34.

Figure 36. Close-up of broken end of second 1/2-inch cable used in mooring 54-inch surface buoy.

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13. ABSTRACT

On 17 July 1961, a sea water environment test was initiated to determine the useful life of a 7/64-inch-diameter galvanized steel cable, sheathed with a 0.020 polyethylene coating. This specific work was undertaken as a part of NCEL Task NUSL-16407, Development of a Container for a Master Repeater Unit (see NCEL Technical Report R-324).

The test cable had a proven breaking strength of 1600 pounds. The test consisted of an underwater mooring of a 32-foot-long, 20-inch-diameter cylinder with 700 pounds of positive buoyancy. This cylinder container was lowered to a depth of 130 feet at its lower end, held by the test cable attached to a 1500-pound concrete clump anchor.

The design life of the test cable was six months. The container was found adrift approximately one mile from its moored position on 23 September 1964, three years and two months after installation.

There are reasons to believe that the test cable's useful life far exceeded its design life due to the protection against sea water corrosion of steel cable provided by polyethylene coating.

unclassified
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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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wire rope	9					
coatings	10					
polyethylene	9					
corrosion	3					
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